

## **11.9 Gutter Flow Calculations**

### **11.9.1 Introduction**

Gutter flow calculations are necessary in order to relate the quantity of flow (Q) in the curbed channel to the spread of water on the shoulder, parking lane, or pavement section. The nomograph on Figure 11-1 can be utilized to solve uniform cross slope channels, composite gutter sections and V shape gutter sections. Figure 11-3 is also very useful in solving composite gutter section problems. Computer programs such as the FHWA HEC 12 program is also very useful for this computation as well as inlet capacity. Example problems for each gutter section are shown in the following sections.

### **11.9.2 Manning's n For Pavements**

**Table 11-3 Manning's n For Streets and Pavement Gutters**

<b>Type of Gutter or Pavement</b>	<b>Manning's n</b>
Concrete gutter, troweled finish	0.012
Asphalt Pavement: Smooth texture	0.013
Rough texture	0.016
Concrete gutter-asphalt pavement Smooth	0.013
Rough	0.015
Concrete pavement Float finish	0.014
Broom finish	0.016
For gutters with small slope, where sediment may accumulate, increase above n values by:	0.002
Reference: USDOT, FHWA, HDS-3 (1961)	

### **11.9.3 Uniform Cross Slope Procedure**

The nomograph in Figure 11-1 is used with the following procedures to find gutter capacity for uniform cross slopes:

CONDITION 1: Find spread (T), given gutter flow (Q).

- Step 1 Determine input parameters, including longitudinal slope (S), cross slope ( $S_x$ ), gutter flow (Q) and Manning's n.
- Step 2 Draw a line between the S and  $S_x$  scales and note where it intersects the turning line.

- Step 3 Draw a line between the intersection point from Step 2 and the appropriate gutter flow value on the capacity scale. If Manning's  $n$  is 0.016, use  $Q$  from Step 1; if not, use the product of  $Q$  and  $n$ .
- Step 4 Read the value of the spread ( $T$ ) at the intersection of the line from Step 3 and the spread scale.

CONDITION 2: Find gutter flow ( $Q$ ), given spread ( $T$ ).

- Step 1 Determine input parameters, including longitudinal slope ( $S$ ), cross slope ( $S_x$ ), spread ( $T$ ) and Manning's  $n$ .
- Step 2 Draw a line between the  $S$  and  $S_x$  scales and note where it intersects the turning line.
- Step 3 Draw a line between the intersection point from Step 2 and the appropriate value on the  $T$  scale. Read the value of  $Q$  or  $Qn$  from the intersection of that line on the capacity scale.
- Step 4 For Manning's  $n$  values of 0.016, the gutter capacity ( $Q$ ) from Step 3 is selected. For other Manning's  $n$  values (see Table 11-3), the gutter capacity times  $n$  ( $Qn$ ) is selected from Step 3 and divided by the appropriate  $n$  value to give the gutter capacity.

#### 11.9.4 Composite Gutter Sections Procedure

Figure 11-3 can be used to find the flow in a gutter section with width ( $W$ ) less than the total spread ( $T$ ). Such calculations are generally used for evaluating composite gutter sections or frontal flow for grate inlets.

CONDITION 1: Find spread ( $T$ ), given flow ( $Q$ ).

- Step 1 Determine input parameters, including longitudinal slope ( $S$ ), cross slope ( $S_x$ ), depressed section slope ( $S_w$ ), depressed section width ( $W$ ), Manning's  $n$ , gutter flow ( $Q$ ) and a trial value of the gutter capacity above the depressed section ( $Q_s$ ). (Example:  $S = 0.01$ ;  $S_x = 0.02$ ;  $S_w = 0.06$ ;  $W = 0.6$  m;  $n = 0.016$ ;  $Q = 0.057$  m<sup>3</sup>/s; try  $Q_s = 0.020$  m<sup>3</sup>/s)
- Step 2 Calculate the gutter flow in  $W$  ( $Q_w$ ), using the equation:
- $$Q_w = Q - Q_s \quad (Q_w = 0.057 - 0.020 = 0.037 \text{ m}^3/\text{s}) \quad (11.5)$$
- Step 3 Calculate the ratios  $Q_w/Q$  and  $S_w/S_x$  and use Figure 11-2 to find an appropriate value of  $W/T$ . ( $Q_w/Q = 0.037/0.057 = 0.65$   $S_w/S_x = 0.06/0.02 = 3$  From Figure 11-2,  $W/T = 0.27$ )
- Step 4 Calculate the spread ( $T$ ) by dividing the depressed section width ( $W$ ) by the value of  $W/T$  from Step 3. ( $T = 0.6/0.27 = 2.22$  m)
- Step 5 Find the spread above the depressed section ( $T_s$ ) by subtracting  $W$  from the value of  $T$  obtained in Step 4. ( $T_s = 2.22 - 0.6 = 1.62$  m)

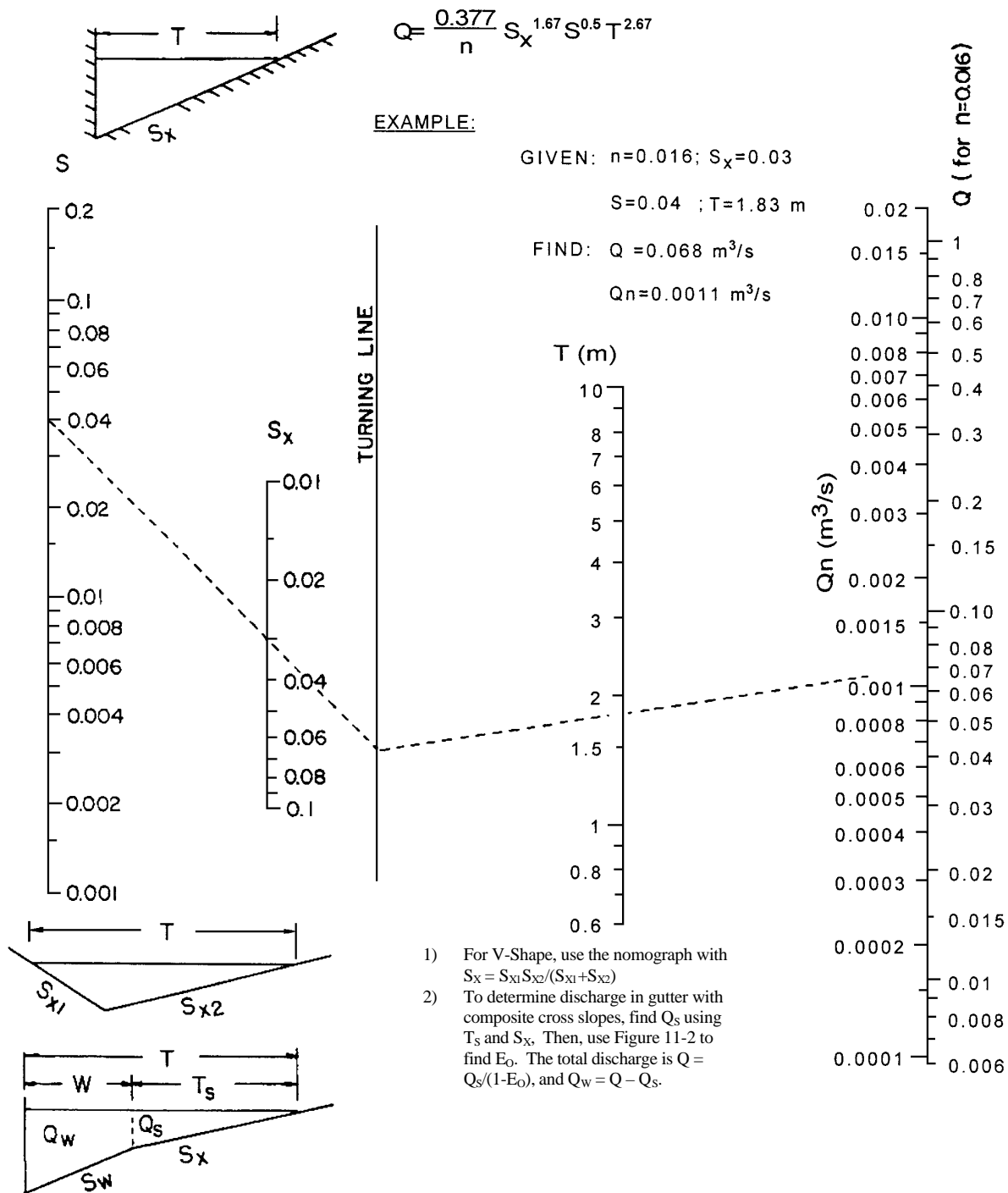
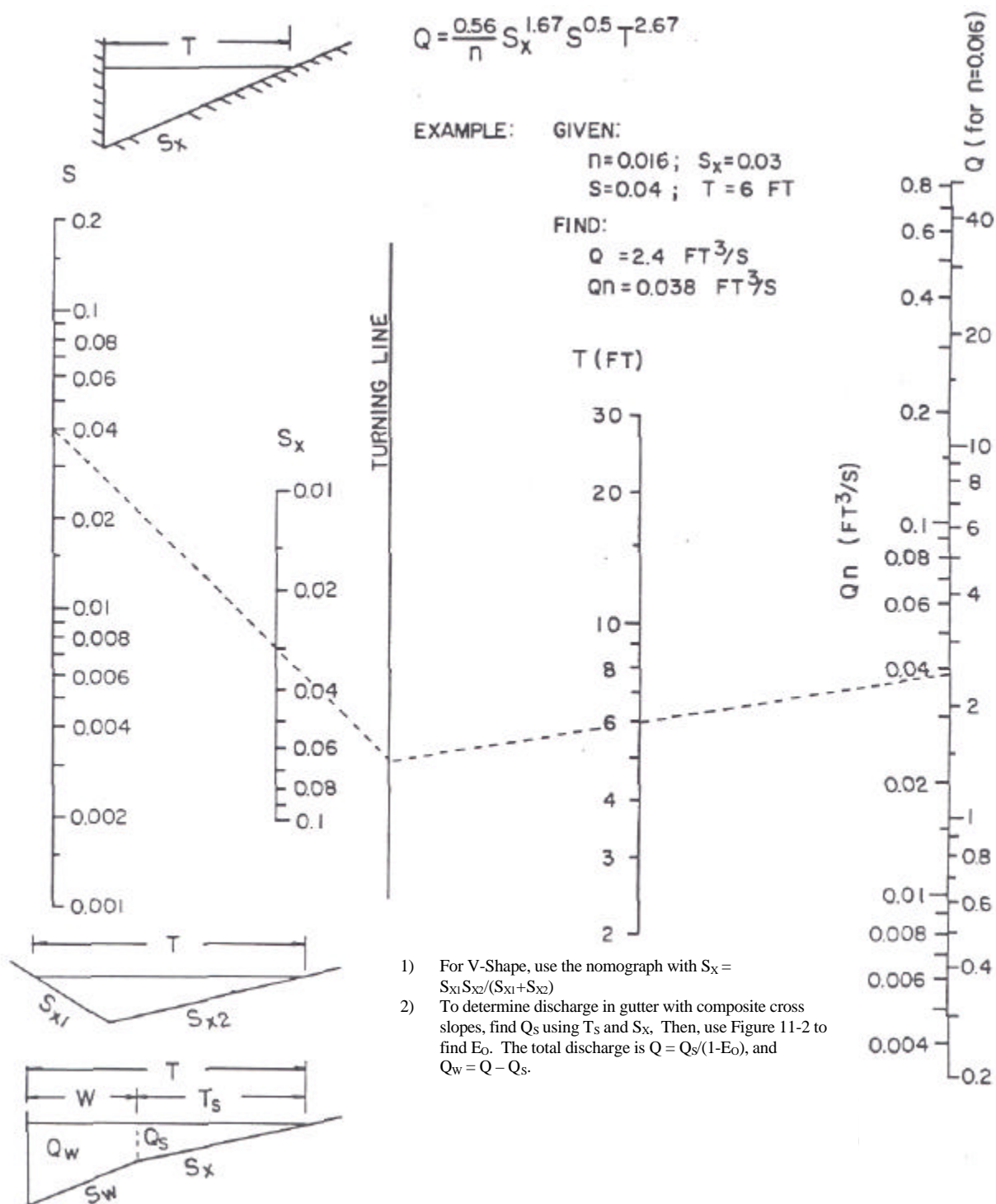


Figure 11-1 Flow In Triangular Gutter Sections – Metric units

Source: HEC 12



**Figure 11-1.1 Flow In Triangular Gutter Sections – English units**

Source: HEC-12

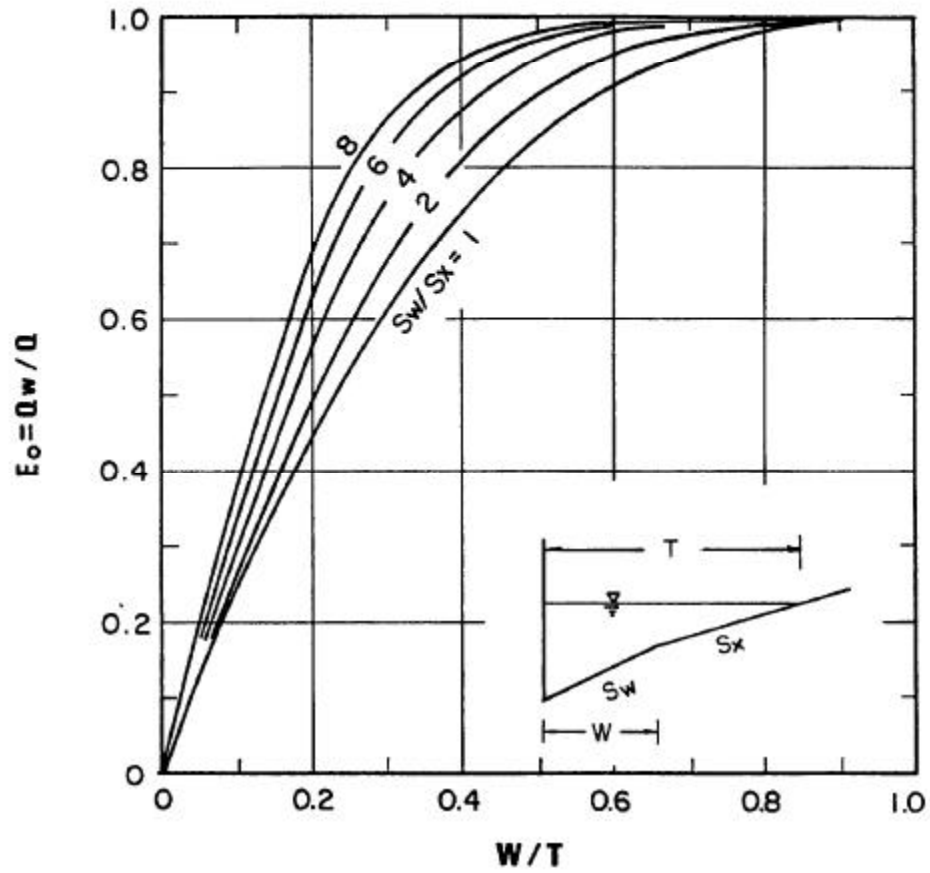


Figure 11-2 Ratio Of Frontal Flow To Total Gutter Flow

Source: HEC-12

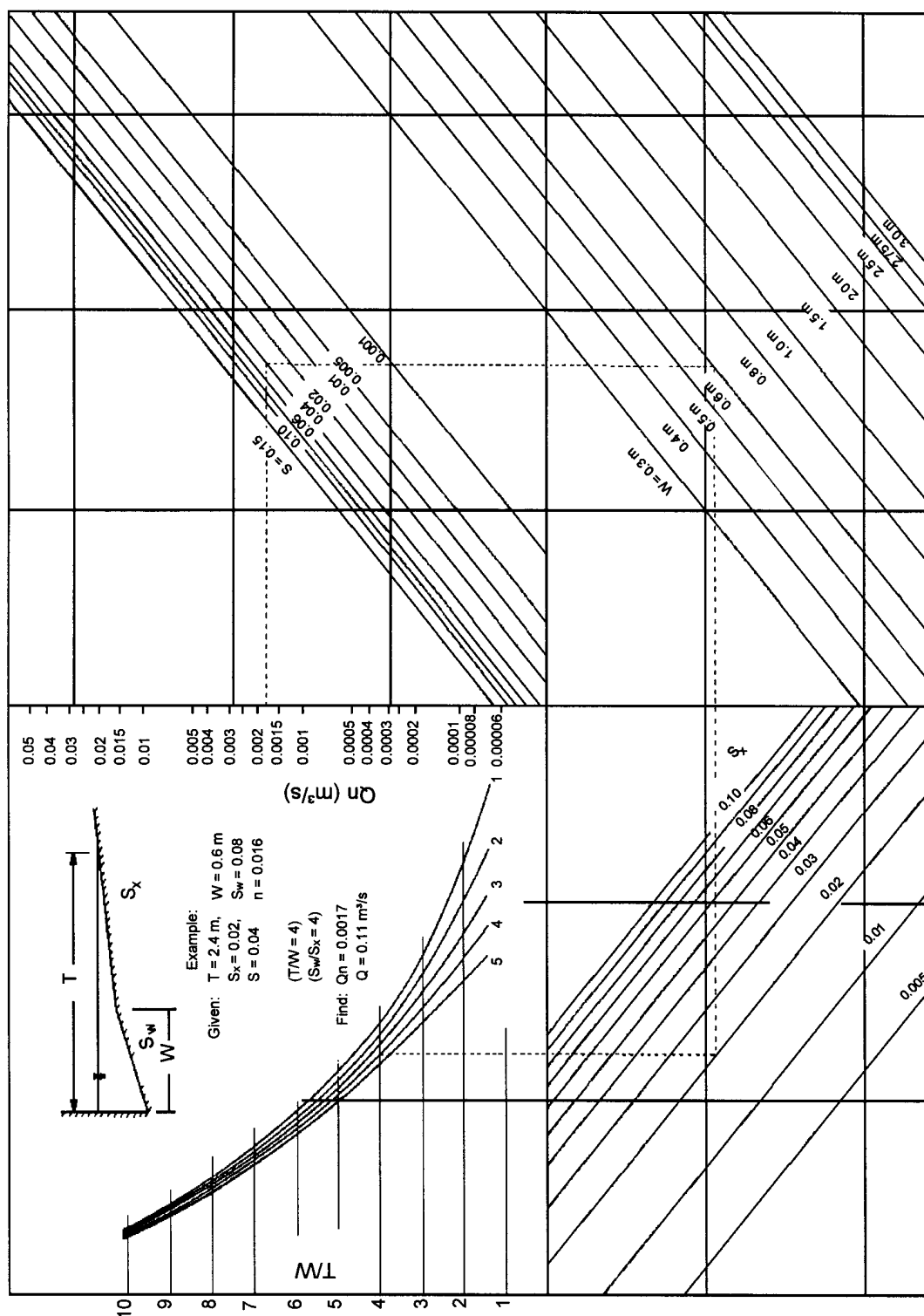
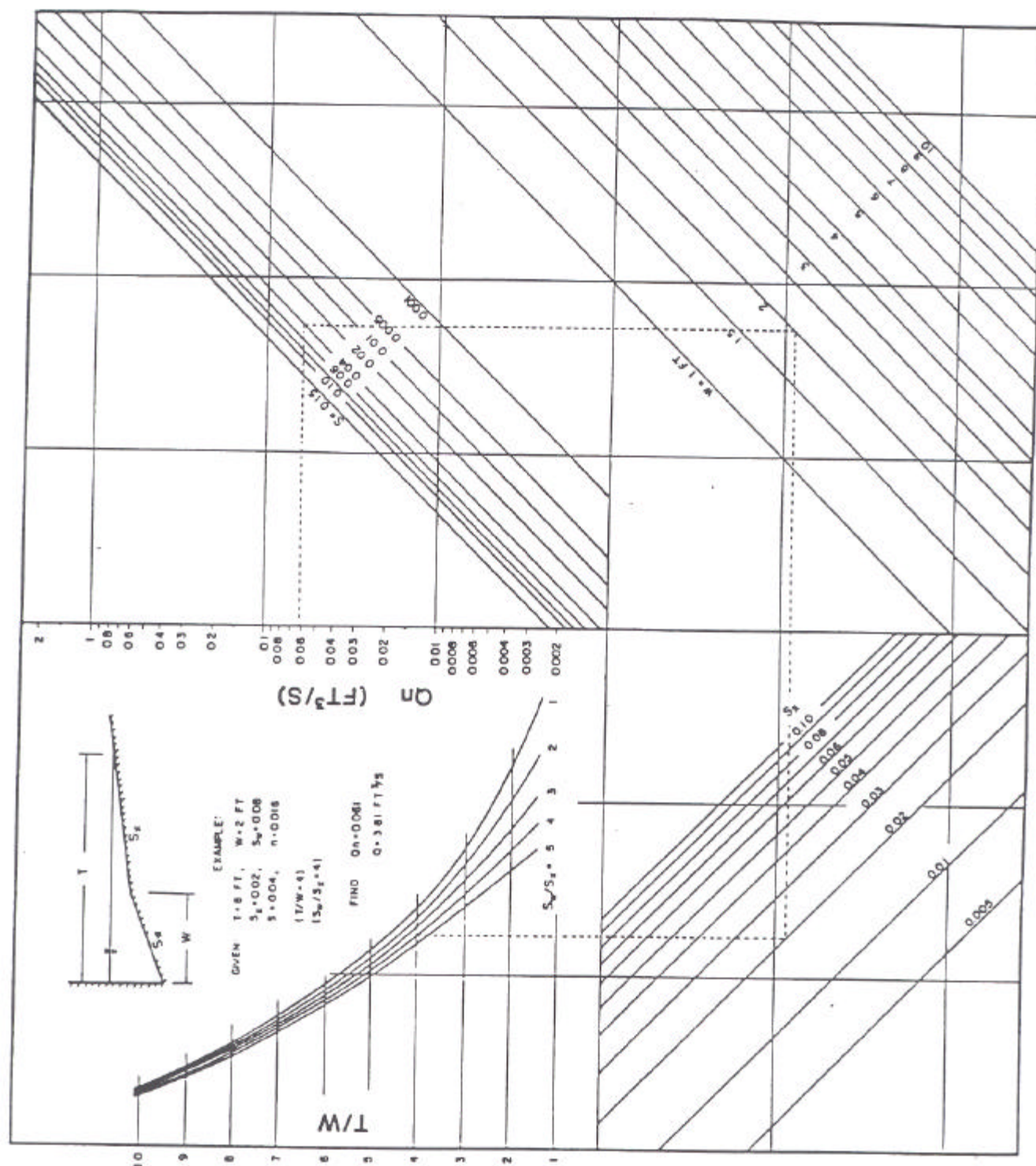


Figure 11-3 Flow In Composite Gutter Sections – Metric units

Source: HEC 12



**Figure 11-3.1 Flow In Composite Gutter Sections – English units**

Source: HEC-12

Step 6 Use the value of  $T_s$  from Step 5 along with Manning's  $n$ ,  $S$  and  $S_x$  to find the actual value of  $Q_s$  from Figure 11-1. (From Figure 11-1  $Q_s = 0.014 \text{ m}^3/\text{s}$ )

Step 7 Compare the value of  $Q_s$  from Step 6 to the trial value from Step 1. If values are not comparable, select a new value of  $Q_s$  and return to Step 1.

(Compare 0.014 to 0.020 "no good," Try  $Q_s = 0.023$ ; then  $0.057 - 0.023 = 0.034$ ; and  $0.034/0.057 = 0.6$ ; From Figure 11-2  $W/T = 0.23$ , then  $T = 0.6/0.23 = 2.61 \text{ m}$  and  $T_s = 2.61 - 0.6 = 2.01 \text{ m}$ . From Fig 11-1,  $Q_s = 0.023 \text{ m}^3/\text{s}$  OK)

ANSWER: Spread  $T = 2.61 \text{ m}$

CONDITION 2: Find gutter flow ( $Q$ ), given spread ( $T$ ).

Step 1 Determine input parameters, including spread ( $T$ ), spread above the depressed section ( $T_s$ ), cross slope ( $S_x$ ), longitudinal slope ( $S$ ), depressed section slope ( $S_w$ ), depressed section width ( $W$ ), Manning's  $n$  and depth of gutter flow ( $d$ ).

EXAMPLE: (Allowable spread  $T = 3.05 \text{ m}$ ;  $W = 0.6 \text{ m}$ ;  $T_s = 3.05 - 0.6 = 2.44 \text{ m}$ ;  $S_x = 0.04$ ;  $S = 0.005 \text{ m/m}$ ;  $S_w = 0.06$ ;  $n = 0.016$ ;  $d = 0.13 \text{ m}$ )

Step 2 Use Figure 11-1 to determine the capacity of the gutter section above the depressed section ( $Q_s$ ). Use the procedure for uniform cross slopes- Condition 2, substituting  $T_s$  for  $T$ . (From Figure 11-1,  $Q_s = 0.085 \text{ m}^3/\text{s}$ )

Step 3 Calculate the ratios  $W/T$  and  $S_w/S_x$ , and from Figure 11-2, find the appropriate value of  $E_o$  (the ratio of  $Q_w/Q$ ). ( $W/T = 0.6/3.05 = 0.2$ ;  $S_w/S_x = 0.06/0.04 = 1.5$ ; From Figure 11-2  $E_o = 0.46$ )

Step 4 Calculate the total gutter flow using the equation:

$$Q = Q_s / (1 - E_o) \quad (11.6)$$

Where:  $Q$  = gutter flow rate,  $\text{m}^3/\text{s}$

$Q_s$  = flow capacity of the gutter section above the depressed section,  $\text{m}^3/\text{s}$

$E_o$  = ratio of frontal flow to total gutter flow ( $Q_w/Q$ )

$$(Q = 0.085 / (1 - 0.46) = 0.157 \text{ m}^3/\text{s})$$

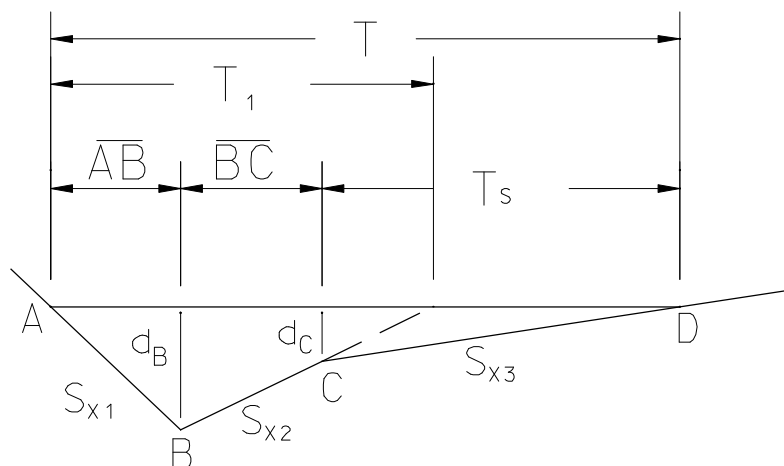
Step 5 Calculate the gutter flow in width ( $W$ ), using equation 11.5.

$$(Q_w = Q - Q_s = 0.157 - 0.085 = 0.072 \text{ m}^3/\text{s})$$

NOTE: Figure 11-3 can also be used to calculate the flow in a composite gutter section.

### 11.9.5 V Type Gutter Sections Procedures

Figure 11-1 can also be used to solve V Type channel problems. The spread (T) can be calculated for a given flow (Q) or the flow can be calculated for a given spread. This method can be used to calculate approximate flow conditions in the triangular channel adjacent to concrete median barriers. It assumes the effective flow is confined to the V channel with spread  $T_1$ .



**Figure 11-4 V Type Gutter**

CONDITION 1: Given flow (Q), find spread (T).

Step 1 Determine input parameters, including longitudinal slope (S), cross slope  $S_x = S_{x1}S_{x2}/(S_{x1}+S_{x2})$ , Manning's n, total flow (Q). (Example:  $S = 0.01$ ,  $S_{x1} = 0.25$ ,  $S_{x2} = 0.04$ ,  $S_{x3} = 0.015$ ,  $n = 0.016$ ,  $Q = 0.050 \text{ m}^3/\text{s}$ , distance  $BC = 0.6\text{m}$ )

Step 2 Calculate  $S_x$   
 $S_x = S_{x1}S_{x2}/(S_{x1} + S_{x2})$        $S_x = (0.25)(0.04)/(0.25 + 0.04) = 0.0345$

Step 3 Solve for  $T_1$  using the nomograph on Figure 11-1.

$T_1$  is a hypothetical width that is correct if it is contained within  $S_{x1}$  and  $S_{x2}$ . From nomograph  $T_1 = 1.94\text{m}$

Step 4 To determine if  $T_1$  is within  $S_{x1}$  and  $S_{x2}$ , compute the flow depth,  $d_B$ , at point B and use this depth to find the horizontal distance between points A and B,  $AB$ .  $d_B$  can be computed using the following geometric relationship.

$$\begin{aligned} T_1 &= (d_B/S_{x1}) + (d_B/S_{x2}), \text{ from which} \\ d_B &= T_1(S_{x1})(S_{x2}) / (S_{x1} + S_{x2}) = (1.94)(0.25)(0.04)/(0.25 + 0.04) \\ d_B &= 0.067 \text{ m (0.22 ft)} \\ AB &= d_B / S_{x1} = 0.067 / 0.25 \\ AB &= 0.27\text{m (0.9 ft)} \\ AC &= AB + 0.6\text{m} = 0.27\text{m} + 0.6\text{m} \\ AC &= 0.87 \text{ m (2.9 ft)} \\ 0.87\text{m} &< T_1 \text{ therefore, spread falls outside V-shaped gutter section.} \end{aligned}$$

Step 5 Solve for the depth at point C,  $d_c$ , and compute the actual spread from edge of gutter section  $T_s$

$$\begin{aligned} d_c &= d_B - BC (S_{x2}) \\ &= (0.067) - (0.60)(0.04) \\ &= 0.043 \text{ m (0.14 ft)} \end{aligned}$$

$$\text{Therefore, } T_s = d_c / S_{x3} = (0.043)/(0.015) = 2.87\text{m (9.4 ft)}$$

Step 6 Find the actual total spread (T).

$$\begin{aligned} T &= T_s + AB + BC \\ T &= 2.87\text{m} + 0.27\text{m} + 0.6\text{m} \\ T &= 3.74 \text{ m (12.3 ft)} \end{aligned}$$

CONDITION 2: Given Spread (T), Find Flow (Q)

Step 1 Determine input parameters such as longitudinal slope (S), Cross slope ( $S_x$ ) =  $S_{x1}S_{x2}/(S_{x1} + S_{x2})$ , Manning's n and allowable spread. (Example:  $n = 0.016$ ,  $S = 0.015$ ,  $S_{x1} = 0.06$ ,  $S_{x2} = 0.04$ ,  $T = 1.83 \text{ m}$ )

Step 2 Calculate  $S_x$

$$S_x = S_{x1}S_{x2}/(S_{x1} + S_{x2}) = (0.06)(0.04)/(0.06 + 0.04) = 0.024$$

Step 3 Using Figure 11-1, Solve for Q

$$\text{For } T = 1.83 \text{ m, } Q = 0.028 \text{ m}^3/\text{s}$$

The equation shown on Figure 11-1 can also be used.

### 11.9.6 Grate Inlets in A Sag

A type "C-L" catch basin in a sag operates as a weir up to a certain depth dependent on the bar configuration and size of the grate (Type A or B) and as an orifice at greater depths. For these types of grates, weir operation continues to a depth of about 0.12m (0.4 ft.) above the top of grate and when depth of water exceeds about 0.43m (1.4 ft.), the grate begins to operate as an orifice. Between depths of about 0.12m (0.4 ft.) and about 0.43m (1.4 ft.), a transition from weir to orifice flow occurs. For a type "C" catch basin the side against the curb is not included in computing the perimeter (P).

The capacity of grate inlets operating as a weir is:

$$Q_i = \frac{CPd^{1.5}}{C_{FS}} \quad (11.7)$$

solving for d:

$$d = \left( \frac{Q_i C_{FS}}{CP} \right)^{2/3}$$

where:

- $Q_1$  = rate of discharge into grate opening, m<sup>3</sup>/s (cfs)
- $P$  = perimeter of grate excluding bar widths and the side against the curb, m (ft)
- $C$  = 1.66 (3.0)
- $d$  = depth of water above grate, m (ft)
- $C_{FS}$  = factor of safety for clogging

The capacity of grate inlets operating as an orifice is:

$$Q_i = \frac{CA(2gd)^{0.5}}{C_{FS}} \quad (11.8)$$

solving for d:

$$d = \left( \frac{Q_i C_{FS}}{CA} \right)^2 / 2g$$

where:

- $Q_1$  = rate of discharge into grate opening, m<sup>3</sup>/s (cfs)
- $C$  = 0.67 orifice coefficient
- $A$  = clear opening area of the grate, m<sup>2</sup> (ft<sup>2</sup>)
- $g$  = 9.81 m/s<sup>2</sup> (32.2 ft/s<sup>2</sup>)
- $d$  = depth of water above grate, m (ft)
- $C_{FS}$  = factor of safety for clogging
  - = 1.0 – Type “C” catch basin with 0% clogging
  - = 2.0 – Type “C-L” catch basin with 50% clogging – high clogging potential
  - = 1.0 <  $C_{FS}$  < 2.0 – Type “C-L” catch basin with 0%–50% clogging – low clogging potential. Typically for expressway medians, swales, and ditches where minimal tree growth is expected, a  $C_{FS}$  = 1.25 for 20% clogging is appropriate.

Between depths over the grate of about 0.12m (0.4 ft.) and about 0.43m (1.4 ft.) the operation of the grate inlet is indefinite due to vortices and other disturbances. The capacity of the grate is somewhere between that given by equations 11.7 and 11.8. The larger depth is used for design purposes.

Because of the vortices and the tendency of trash to collect on the grate, a factor of safety for clogging has been added to equations 11.7 and 11.8. For Type “C-L” catch basins with a high potential for clogging a factor of safety of 2 should be used. Where danger of clogging is slight, a factor of safety less than two might be used. When a type “C” catch basin is used, the curb opening provides the safety factor from clogging therefore the factor of safety is one (1.0).

DOT GRATE AREAS AND PERIMETERS ARE AS FOLLOWS:

**Type "C" Catch Basin with Type A Grate**

Total Steel Frame Length	3'- 1 3/4"	or 0.9588 m	(3.1458 ft)
2 Angles 2 1/2" Wide	2 (2 1/2")	or 0.1270 m	(0.4167 ft)
8 Bars 5/8" Wide	8 (5/8")	or 0.1270 m	(0.4167 ft)
Length Clear Opening		or <b>0.7048 m</b>	<b>(2.3124 ft)</b>

Total Steel Frame Width	1'- 7 5/8"	or 0.4985 m	(1.6354 ft)
9 Bars 3/8" Wide	9 (3/8")	or 0.0857 m	(0.2813 ft)
Width Clear Opening		or <b>0.4127 m</b>	<b>(1.3541 ft)</b>

Perimeter (P)=	2(1.3541') + 2.3124' =	1.53 m	(5.02 ft)
Area (A)=	1.3541' x 2.3124' =	0.29 m <sup>2</sup>	(3.13 ft <sup>2</sup> )

**Type "C" Catch Basin with Type A Grate Double Grate Type I**

Perimeter (P)=	2(1.3541') + (2)2.3124' =	2.24 m	(7.33 ft)
Area (A)=	1.3541' x 2.3124' x 2 =	0.58 m <sup>2</sup>	(6.26 ft <sup>2</sup> )

**Type "C-L" Catch Basin with Type A Grate**

Perimeter (P)=	2(1.3541') + (2)2.3124' =	2.24 m	(7.33 ft)
Area (A)=	1.3541' x 2.3124' =	0.29 m <sup>2</sup>	(3.13 ft <sup>2</sup> )

**Type "C-L" Catch Basin with Type A Grate Double Grate Type I or II**

Perimeter (P)=	2(1.3541') + (4)2.3124' =	3.64 m	(11.96 ft)
Area (A)=	1.3541' x 2.3124' x 2 =	0.58 m <sup>2</sup>	(6.26 ft <sup>2</sup> )

It should be noted that these perimeters and areas are for Type A grate. These may also be used with Type B grates as the difference is insignificant.

### 11.9.7 Slotted Inlets On Grade

Wide experience with the debris handling capabilities of slotted inlets is not available. Deposition in the pipe is the problem most commonly encountered, and the inlet is accessible for cleaning only with a high pressure water jet. Slotted inlets are effective pavement drainage inlets which have a variety of applications. They can be used on curbed or uncurbed sections and offer little interference to traffic operations.

Slotted Inlets On Grade

Flow interception by slotted inlets is side weir and the flow is subjected to lateral acceleration due

to the cross slope of the pavement. Thus the equation with a straight cross slope is expressed by:

$$L_T = KQ^{0.42}S^{0.3}(1/nS_x)^{0.6} \quad (11.9)$$

where:

$$K = 0.817 (0.6)$$

$L_T$  = slotted inlet length required to intercept 100% of the gutter flow, m (ft)

$S$  = longitudinal slope m/m (ft/ft)

$S_x$  = cross slope m/m (ft/ft)

The efficiency of slotted inlets shorter than the length required for total interception is expressed by:

$$E = 1 - (1 - L/L_T)^{1.8} \quad (11.10)$$

Where:

$L$  = slotted inlet length, m (ft)

Figure 11-5 is a nomograph for the solution of equation 11.9, and Figure 11-6 provides a solution of equation 11.10.

The following example illustrates the use of this procedure.

Given:  $Q = 0.113 \text{ m}^3/\text{s}$   $n = 0.016$   
 $S = 0.010$   $S_x = 0.02$

Find:  $Q_{IN}$  = for 6.1m of slotted inlet

Solution: From Figure 11-6  $L_T = 10.36\text{m}$   
 $L/L_T = 6.1/10.36 = 0.58$

From Figure 11-7  $E = 0.79$   
 $Q_{IN} = (E)(Q) = 0.79 \times 0.113 = 0.089 \text{ m}^3/\text{s}$

### 11.9.8 Slotted Inlets In A Sag

Slotted inlets are not recommended for sag conditions since the pipe would be on a zero grade resulting in non cleaning velocities. However, if at any time it becomes necessary to design a slotted inlet in a sag, the following procedure is to be used.

Slotted inlets in sag locations perform as weirs to depths of about 0.06m (0.2 ft), dependent on slot width and length. At depths greater than about 0.12m (0.4 ft), they perform as orifices. Between these depths, flow is in a transition stage. The interception capacity of a slotted inlet operating as an orifice can be computed by the following equation:

$$Q_i = 0.8LW(2gd)^{0.5} \quad (11.11)$$

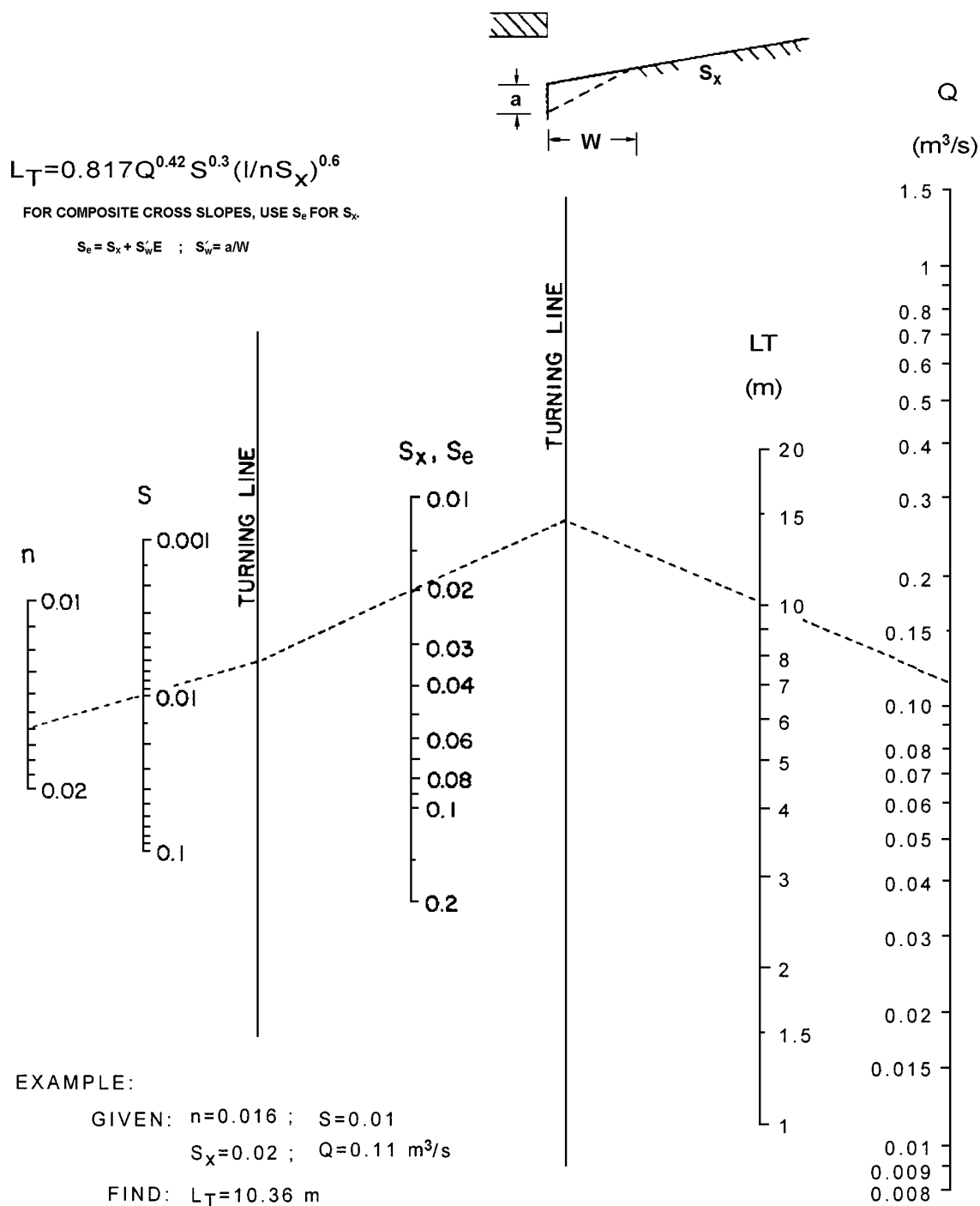
where:

- W = width of slot, m (ft)
- L = length of slot, m (ft)
- d = depth of water at slot, m (ft)
- g = 9.81 m/s<sup>2</sup> (32.2 ft/s<sup>2</sup>)

For a slot width of 44mm (1 ¾ in), the above equation becomes:

$$Q_i = 0.156Ld^{0.5} \quad ( Q_i = 9.37Ld^{0.5} ) \quad (11.12)$$

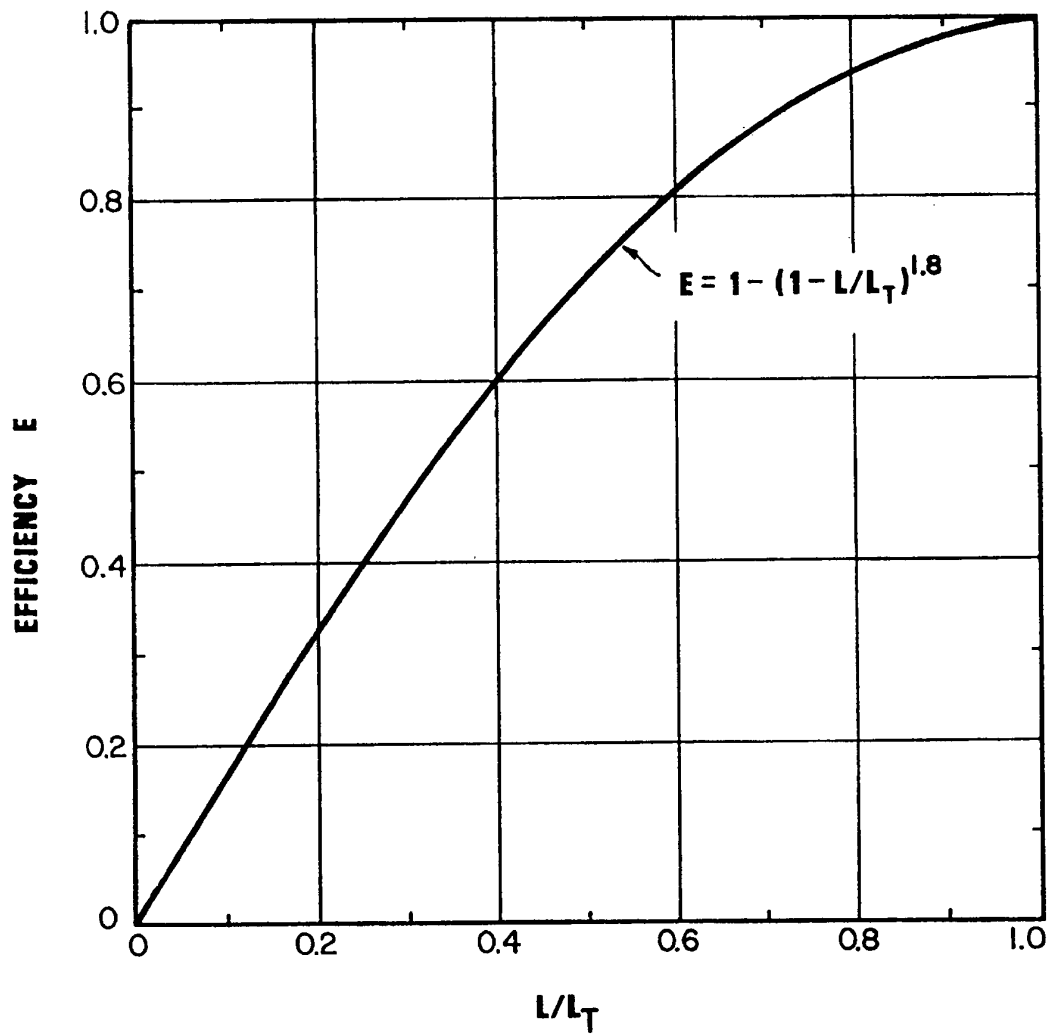
The interception capacity of slotted inlets at depths between 0.06m (0.2 ft) and 0.12m (0.4 ft) can be computed by use of the orifice equation. The orifice coefficient varies with depth, slot width, and the length of the slotted inlet. Figure 11-7 provides solutions for weir flow and a plot representing data at depths between weir and orifice flow.



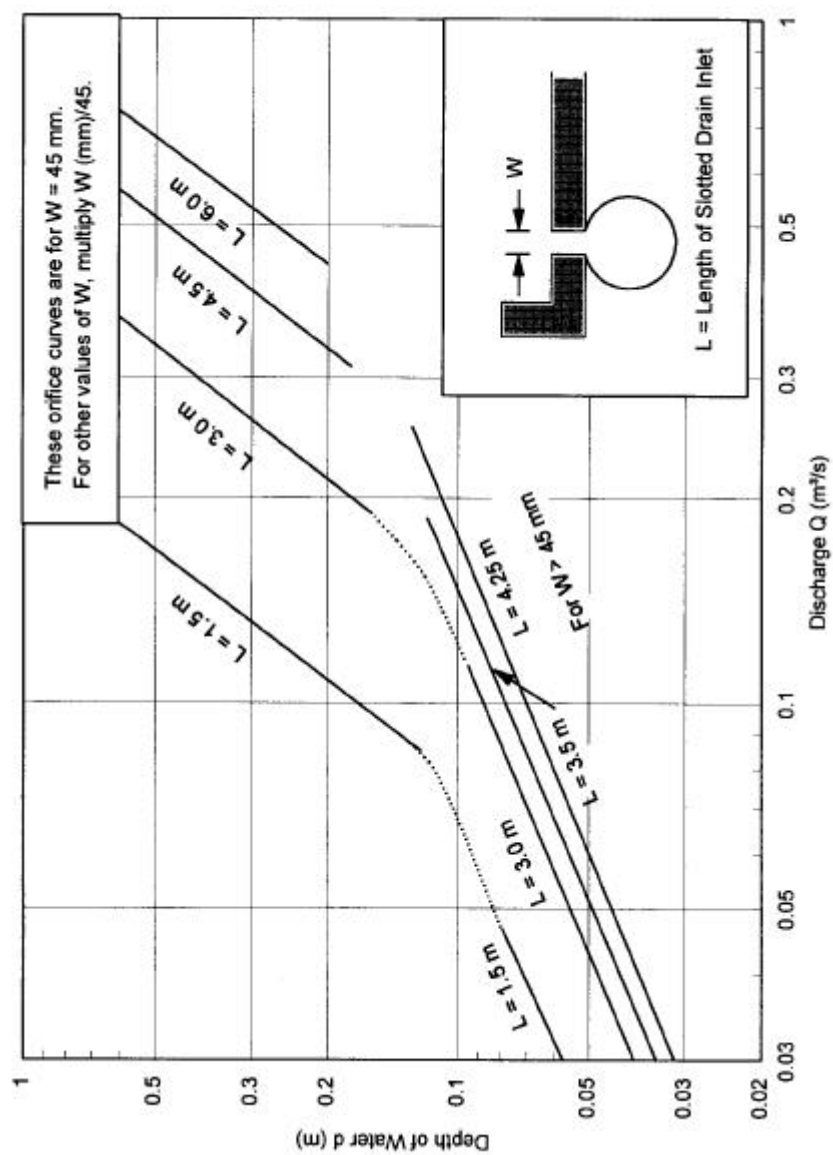
**Figure 11-5 Curb-Opening And Longitudinal Slotted Drain  
Inlet Length For Total Interception – Metric units**

Source: HEC-12



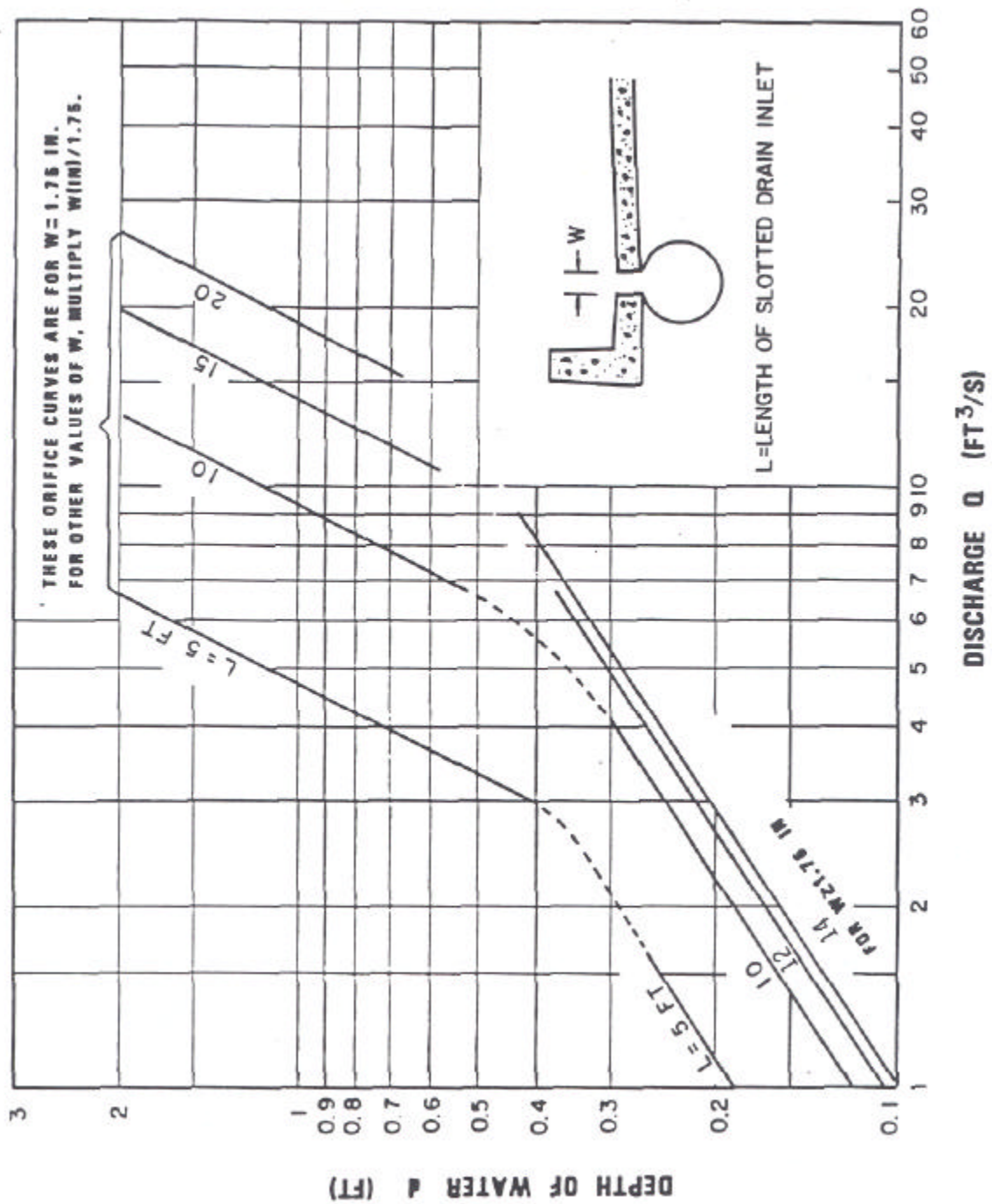


**Figure 11-6 Curb-Opening And Slotted Drain Inlet Interception Efficiency**  
Source: HEC-12



**Figure 11-7 Slotted Drain Inlet Capacity In Sump Locations – Metric units**

Source: HEC-12



**Figure 11-7.1 Slotted Drain Inlet Capacity in Sump Locations – English units**

Source: HEC-12

### 11.9.9 Inlet Spacing Computations (Gutter Flow Analysis)

In order to design the location of the inlets for a given project, information such as a layout or plan sheet suitable for outlining drainage areas, road profiles, typical cross sections, grading cross sections, superelevation diagrams and contour maps are necessary. The gutter flow analysis worksheet, Table 11-4, should be used to document the computations. A step by step procedure is as follows:

- Step 1 Complete the blanks on top of the sheet to identify the job by project, town, route, date, your initials, roadway type, ADT, design speed and allowable width of flooding.
- Step 2 Mark on the plan the location of inlets which are necessary even without considering any specific drainage area. See Section 11.8.7 Inlet Locations for additional information.
- Step 3 Start at one end of the job, at one high point and work towards the low point, then space from the other high point back to the same low point.
- Step 4 Select a trial drainage area approximately 90 to 150 m (300 to 500 ft) below the high point and outline the area including any area that may come over the curb. (Use drainage area maps.) Where practical, large areas of behind the curb drainage should be intercepted before it reaches the highway.
- Step 5 Describe the location of the proposed inlet by station and location from centerline. Enter in Col. 1. A sketch of the cross section should be provided in the open area of the computation sheet showing lane and shoulder arrangement and the available width of flow.
- Step 6 Compute the drainage area in hectares (acres) and enter in Col 2.
- Step 7 Select a C value from one of the tables in Chapter 6 and compute a weighted value based on area and cover type as described in Section 11.5.3 and enter in Col 3.
- Step 8 Compute a time of concentration for the first inlet. This will be the travel time from the hydraulically most remote point in the drainage area to the inlet. See additional discussion in Section 11.5.5 and in Chapter 6. The minimum time of concentration should be 5 min. Enter value in Col 4.
- Step 9 Select a rainfall intensity at the  $t_c$  for the design frequency (Chapter 6, Appendix B). Enter in Col. 5.
- Step 10 Compute the AC to the inlet  $\text{Col 2} \times \text{Col 3}$ . Enter in Col 6.
- Step 11 The total AC to the inlet is obtained by adding the AC bypassing the previous inlet and the AC for the inlet ( $\text{Col. 6} + \text{Col. 14}$ ). Enter in Col. 7. Note for the first inlet  $\text{AC} = \text{Total AC}$ .
- Step 12 Calculate Q by multiplying  $.00278 \times \text{Col. 5} \times \text{Col. 7}$  ( $1 \times \text{Col. 5} \times \text{Col. 7}$ ). Enter in Col. 8.

- Step 13 Determine the gutter slope at the inlet from the profile grade and the cross slope of shoulder and enter in Col. 9 and Col. 10, respectively (check effect of superelevation).
- Step 14 Using Figure 11-1 or an approved computer model, determine the spread T (width of flow) and enter in Col. 12 and calculate the depth d at the curb by multiplying T times the cross slope(s) and enter in Col. 11. Compare with the allowable spread as determined by the design criteria in Table 11.2. If Col. 11 is less than the curb height and Col. 12 is near the allowable spread, continue on to step 15. If not OK, expand or decrease the drainage area to meet the criteria and repeat steps 5 through 13. Continue these repetitions until column 12 is near the allowable spread then proceed to step 4.
- Step 15 Calculate Q bypassing the inlet. The portion of flow that is beyond the width of the grate will be used to determine the bypass Q. Enter in Col. 13.

$$Q_{bypass} = Q_{total} \left( \frac{(T - G)^2}{T^2} \right)$$

where

G = width of grate, m (ft.)

T = spread from Col. 12, m (ft.)

- Step 16 Determine the AC bypassing the inlet by dividing Col. 13 by Col. 5. Enter in Col. 14.
- Step 17 Calculate the AC entering the inlet. Col. 7-Col. 14. Enter in Col. 15.
- Step 18 Proceed to the next inlet downgrade. Select an area 90 to 120m (300 to 400 ft) below the first inlet as a first trail. Repeat Steps 5 through 17 considering only the area between inlets.
- Step 19 Go back to step 18 and repeat step 5 through step 17 for each subsequent inlet.
- Step 20 Inlets located in sag locations proceed to Section 11.9.10.

### 11.9.10 Low Point Analysis Computations

The following step by step procedure should be used to determine the depth and width of flow for inlets in sag locations. Table 11-5 should be used to document the computations.

- Step 1 Describe the location of the proposed lot point inlet by station and location from centerline. Enter in Col. 1. A sketch of the cross section should be provided in the open area of the computation sheet showing lane and shoulder arrangement and the available width of flow.
- Step 2 Compute the drainage area in hectares (acres) and enter in Col 2.

- Step 3 Select a C value from one of the tables in Chapter 6 and compute a weighted value based on area and cover type as described in Section 11.5.3 and enter in Col 3.
- Step 4 Compute a time of concentration for the low point inlet. This will be the travel time from the hydraulically most remote point in the drainage area to the inlet. See additional discussion in Section 11.5.5 and in Chapter 6. The minimum time of concentration should be 5 min. Enter value in Col 4.
- Step 5 Select a rainfall intensity at the  $t_c$  for the design frequency (Chapter 6, Appendix B). Enter in Col. 5.
- Step 6 Compute the AC to the inlet Col 2 X Col 3. Enter in Col 6.
- Step 7 Referencing Table 11-5, select the “AC bypassing inlet” from the inlet just upstream and left of the low point inlet. Enter in Col. 7.
- Step 8 Referencing Table 11-5, select the “AC bypassing inlet” from the inlet just upstream and right of the low point inlet. Enter in col. 8.
- Step 9 Calculate the total AC by adding Col. 6 + Col. 7 + Col. 8. Enter in Col. 9.
- Step 10 Calculate the total Q to the low point inlet by multiplying .00278 X Col. 5 X Col. 9 (1 X Col. 5 X Col. 9). Enter in Col. 10.
- Step 11 Enter the cross slope of shoulder in Col. 11.
- Step 12 Calculate the depth of flow using equations 11.7 and 11.8. Enter in Col. 12.

Type “C-L” catch basins must have a clogging factor of safety included when determining depth of flow.

$C_{fs} = 2$  - Depressed expressway sag, depressed parking lots, and other depressed locations.

$C_{fs} = 1.25$  - Expressway medians, swales, and ditches where minimal tree growth is expected.

Type “C” catch basins do not require a clogging factor as the curb opening provides the necessary safety factor.

Therefore  $C_{fs} = 1.0$

- Step 13 Determine the width of flow by dividing Col. 12 by Col. 11. Enter in Col. 13.